

WHAT IS CLAIMED IS:

- 1 1. A method for simultaneously measuring voltage and current in a primary high voltage
2 conductor, the method comprising:
3 monitoring a current and a voltage on the primary conductor using a current transformer
4 to produce current and voltage information on a secondary winding of the current transformer;
5 using the voltage information present on the secondary winding to provide a voltage
6 measurement output representative of the voltage present on the primary conductor; and
7 using the current information present on the secondary winding to provide a current
8 measurement output representative of the current flowing on the high voltage conductor.
- 1 2. The method of claim 1 wherein using the voltage information comprises using a
2 capacitive voltage divider including a first capacitance and a second capacitance to provide the
3 voltage measurement output.
- 1 3. The method of claim 2 wherein the first capacitance consists of a parasitic capacitance
2 between the high voltage conductor and the secondary winding of the current transformer, and
3 the second capacitance consists of a parasitic capacitance between the secondary winding of the
4 current transformer and a transformer core of the current transformer connected to a reference
5 potential.
- 1 4. The method of claim 3 wherein the reference potential is ground.
- 1 5. The method of claim 3 wherein the second capacitance has a value from approximately
2 0.001 microfarads to approximately 10 microfarads.
- 1 6. The method of claim 3 further comprising adjusting the second capacitance by adjusting
2 a current transformer geometry.
- 1 7. The method of claim 3 further comprising adjusting the second capacitance by adding
2 an external capacitance.

1 8. The method of claim 3 wherein the second capacitance forms a high pass filter network
2 in combination with a drain resistor connected between the current transformer secondary
3 winding and the reference potential.

1 9. The method of claim 8 wherein a cutoff frequency of the filter is set between
2 approximately 1 hertz and approximately 0.001 hertz.

1 10. The method of claim 1 wherein using the current information comprises using an
2 auxiliary transformer to provide the current measurement output.

1 11. The method of claim 1 wherein using the current information comprises using an
2 operational amplifier and burden resistor to provide the current measurement output.

1 12. The method of claim 1 further comprising measuring a neutral current of a multi-phase
2 system.

1 13. The method of claim 12 wherein measuring the neutral current comprises using a
2 transformer including a separate winding for each phase.

1 14. The method of claim 1 further comprising protecting the current transformer secondary
2 winding from insulation failure induced by a transient voltage.

1 15. The method of claim 14 wherein protecting the current transformer comprises using a
2 surge suppressor connected between the current transformer secondary winding and a reference
3 potential.

1 16. The method of claim 1 further comprising canceling from the voltage measurement
2 crosstalk introduced by one or more additional voltage phases in a multi-phase system by:
3 obtaining an additional phase voltage measurement for each of the one or more
4 additional phases of the multi-phase system;

5 generating a product for each additional phase by multiplying each additional phase
6 voltage measurement by a corresponding predetermined constant; and
7 subtracting from the voltage measurement the product for each additional phase.

1 17. The method of claim 16 wherein the multi-phase system comprises three phases, such
2 that there are two additional phases.

1 18. The method of claim 2 wherein the first capacitance comprises a parasitic capacitance
2 between the high voltage conductor and the secondary winding of the current transformer, and
3 the second capacitance comprises a parasitic capacitance between the secondary winding of the
4 current transformer and a transformer core of the current transformer connected to a reference
5 potential.

1 19. An apparatus for simultaneously measuring voltage and current in a primary high
2 voltage conductor, the apparatus comprising:

3 a current transformer comprising a secondary winding and a transformer core, the
4 current transformer being electro-magnetically coupled to a high voltage conductor;
5 a capacitive voltage divider comprising a first capacitance between the high voltage
6 conductor and the secondary winding of the current transformer and a second capacitance
7 between the secondary winding of the current transformer and the transformer core;
8 a voltage measurement circuit connected to the current transformer; and
9 a current measurement circuit connected to the current transformer.

1 20. The simultaneous voltage and current measuring apparatus of claim 19 wherein the first
2 capacitance consists of a parasitic capacitance between the high voltage conductor and the
3 secondary winding and the second capacitance consists of a parasitic capacitance between the
4 secondary winding and the transformer core.

1 21. The simultaneous voltage and current measuring apparatus of claim 20 wherein the
2 transformer core is connected to a reference potential.

1 22. The simultaneous voltage and current measuring apparatus of claim 21 wherein the
2 reference potential is ground.

1 23. The simultaneous voltage and current measuring apparatus of claim 20 wherein the
2 second capacitance has a value from approximately 0.001 microfarads to approximately 10
3 microfarads.

1 24. The simultaneous voltage and current measuring apparatus of claim 21 wherein the
2 second capacitance forms a high pass filter network in combination with a drain resistor
3 connected between the current transformer secondary winding and the reference potential.

1 25. The simultaneous voltage and current measuring apparatus of claim 24 wherein a cutoff
2 frequency of the filter is set between approximately 1 hertz and approximately 0.001 hertz.

1 26. The simultaneous voltage and current measuring apparatus of claim 19 wherein the
2 current measurement circuit comprises an auxiliary transformer.

1 27. The simultaneous voltage and current measuring apparatus of claim 19 wherein the
2 current measurement circuit comprises:

3 an operational amplifier including a first input terminal connected to the current
4 transformer and a second input terminal connected to the ground; and
5 a burden resistor connected between the first input terminal and the second input
6 terminal of the operational amplifier.

1 28. The simultaneous voltage and current measuring apparatus of claim 27 further
2 comprising a surge protection device connected between the current transformer and ground.

1 29. The simultaneous voltage and current measuring apparatus of claim 19 wherein the
2 voltage measurement circuit comprises:

3 an operational amplifier including a first input terminal, a second terminal connected to
4 ground, and an output terminal;

5 a drain resistor connected between the first input terminal of the operational amplifier
6 and the second input terminal of the operational amplifier;

7 a first resistor connected between the first input terminal of the operational amplifier
8 and a first terminal of the current transformer; and

9 a second resistor connected between the first input terminal of the operational amplifier
10 and a second terminal of the current transformer.

1 30. The simultaneous voltage and current measuring apparatus of claim 29 further
2 comprising a surge protection device connected between the current transformer and ground.

1 31. The simultaneous voltage and current measuring apparatus of claim 19 wherein the first
2 capacitance comprises a parasitic capacitance between the high voltage conductor and the
3 secondary winding and the second capacitance comprises a parasitic capacitance between the
4 secondary winding and the transformer core.

1 32. An apparatus for simultaneously measuring voltage and current in a primary high
2 voltage conductor for each individual phase in a multi-phase system and for measuring a
3 neutral current of the multi-phase system, the apparatus comprising:

4 a current transformer associated with each individual phase in the multi-phase system,
5 each current transformer comprising a secondary winding and a transformer core, and each
6 current transformer being electro-magnetically coupled to a high voltage conductor for the
7 associated phase;

8 a capacitive voltage divider associated with each individual phase in the multi-phase
9 system, each capacitive voltage divider comprising a first capacitance between the high voltage
10 conductor corresponding to the associated phase and the secondary winding of the current
11 transformer for that phase, and a second capacitance between the secondary winding and the
12 transformer core of the associated current transformer for that phase;

13 a voltage measurement circuit associated with each individual phase in the multi-phase
14 system, each voltage measurement circuit being connected to the current transformer for the
15 associated phase;

16 a current measurement circuit associated with each individual phase in the multi-phase
17 system, each current measuring circuit being connected to the current transformer for the
18 associated phase; and

19 ¶ a neutral current measuring circuit connected to the current transformers.

1 33. The apparatus of claim 32 wherein, for each capacitive voltage divider, the first
2 capacitance consists of a parasitic capacitance between the associated high voltage conductor
3 and the secondary winding, and the second capacitance consists of a parasitic capacitance
4 between the secondary winding and the transformer core.

1 34. The apparatus of claim 33 wherein, for each capacitive voltage divider, the transformer
2 core is connected to a reference potential.

1 35. The apparatus of claim 34 wherein the reference potential is ground.

1 36. The apparatus of claim 33 wherein the second capacitance has a value from
2 approximately 0.001 microfarads to approximately 10 microfarads.

1 37. The apparatus of claim 34 wherein the second capacitance forms a high pass filter
2 network in combination with a drain resistor connected between the current transformer
3 secondary winding and the reference potential.

1 38. The apparatus of claim 37 wherein a cutoff frequency of the filter is set between
2 approximately 1 hertz and approximately 0.001 hertz.

1 39. The apparatus of claim 32 wherein each current measurement circuit comprises an
2 auxiliary transformer.

1 40. The apparatus of claim 32 wherein each current measurement circuit comprises:
2 an operational amplifier including a first input terminal connected to the current
3 transformer and a second input terminal connected to ground; and

4 a burden resistor connected between the first input terminal and the second input
5 terminal of the operational amplifier.

1 41. The apparatus of claim 40 further comprising a surge protection device connected
2 between each current transformer and ground.

1 42. The apparatus of claim 32 wherein each voltage measurement circuit further comprises:
2 an operational amplifier including a first input terminal, a second terminal connected to
3 ground, and an output terminal;

4 a drain resistor connected between the first input terminal of the operational amplifier
5 and the second input terminal of the operational amplifier;

6 a first resistor connected between the first input terminal of the operational amplifier
7 and a first terminal of the current transformer; and

8 a second resistor connected between the first input terminal of the operational amplifier
9 and a second terminal of the current transformer.

1 43. The apparatus of claim 42 further comprising a surge protection device connected
2 between each current transformer and ground.

1 44. The apparatus of claim 32 wherein the neutral current measuring circuit comprises a
2 transformer, the transformer including a secondary winding for each individual phase of the
3 multi-phase system.

1 45. The apparatus of claim 32 further comprising a crosstalk cancellation circuit connected
2 to the voltage measurement circuit associated with each individual phase in the multi-phase
3 system, wherein the crosstalk cancellation circuit is connected to receive a voltage
4 measurement input for each individual phase associated with the multi-phase system and to
5 correct a voltage measurement to account for crosstalk between the phases.

1 46. The apparatus of claim 45 wherein the crosstalk cancellation circuit comprises:
2 an operational amplifier including a first input terminal, a second input terminal, and an
3 output terminal;
4 a voltage input associated with an individual phase of the multi-phase system connected
5 to the first input terminal of the operational amplifier;
6 a resistor associated with each additional phase of the multi-phase system connected
7 between a voltage input for the associated additional phase and the second input terminal of the
8 operational amplifier; and
9 a connecting resistor connected between the second input terminal of the operational
10 amplifier and the output of the operational amplifier.

1 47. The apparatus of claim 46 wherein the multi-phase system comprises three phases, such
2 that there are two additional phases.

1 48. The apparatus of claim 47 wherein:
2 the voltage input associated with an individual phase of the multi-phase system further
3 comprises a voltage input associated with a first phase; and
4 the resistor associated with each additional phase further comprises:
5 a first resistor associated with a second phase connected between a voltage input for the
6 second phase and the second input terminal of the operational amplifier; and
7 a second resistor associated with a third phase connected between a voltage input for the
8 third phase and the second input terminal of the operational amplifier.

1 49. The apparatus of claim 32 wherein the multi-phase system comprises three phases.

1 50. The apparatus of claim 32 wherein, for each capacitive voltage divider, the first
2 capacitance comprises a parasitic capacitance between the associated high voltage conductor
3 and the secondary winding, and the second capacitance comprises a parasitic capacitance
4 between the secondary winding and the transformer core.

1 51. The apparatus of claim 50 wherein the transformer core is connected to a reference
2 potential.

1 52. An apparatus for simultaneously measuring voltage and current in a primary high
2 voltage conductor, the apparatus comprising:

3 a current transformer comprising a secondary winding and a transformer core, the
4 current transformer being electro-magnetically coupled to a high voltage conductor;

5 a capacitive voltage divider comprising a first capacitance between the high voltage
6 conductor and the secondary winding of the current transformer and a second capacitance
7 between the secondary winding of the current transformer and the transformer core;

8 means for measuring voltage in the primary high voltage conductor using the current
9 transformer; and

10 means for measuring current in the primary high voltage conductor using the current
11 transformer.

1 53. The simultaneous voltage and current measuring apparatus of claim 52 wherein the first
2 capacitance consists of a parasitic capacitance between the high voltage conductor and the
3 secondary winding and the second capacitance consists of a parasitic capacitance between the
4 secondary winding and the transformer core.

1 54. The simultaneous voltage and current measuring apparatus of claim 52 wherein the first
2 capacitance comprises a parasitic capacitance between the high voltage conductor and the
3 secondary winding and the second capacitance comprises a parasitic capacitance between the
4 secondary winding and the transformer core.

1 55. An apparatus for simultaneously measuring voltage and current in a primary high
2 voltage conductor for each individual phase in a multi-phase system and for measuring a
3 neutral current of the multi-phase system, the apparatus comprising:

4 a current transformer associated with each individual phase in the multi-phase system,
5 each current transformer comprising a secondary winding and a transformer core, and each

6 current transformer being electro-magnetically coupled to a high voltage conductor for the
7 associated phase;

8 a capacitive voltage divider associated with each individual phase in the multi-phase
9 system, each capacitive voltage divider comprising a first capacitance between the high voltage
10 conductor corresponding to the associated phase and the secondary winding of the current
11 transformer for that phase and a second capacitance between the secondary winding and the
12 transformer core of the associated current transformer for that phase;

13 means for measuring voltage in the primary high voltage conductor for each individual
14 phase in the multi-phase system using the current transformers;

15 means for measuring current in the primary high voltage conductor for each individual
16 phase in the multi-phase system using the current transformers; and

17 | means for measuring a neutral current using the current transformers.

1 56. The apparatus of claim 55 wherein, for each capacitive voltage divider, the first
2 capacitance consists of a parasitic capacitance between the associated high voltage conductor
3 and the secondary winding and the second capacitance consists of a parasitic capacitance
4 between the secondary winding and the transformer core.

1 57. The apparatus of claim 56, wherein the transformer core is connected to a reference
2 potential.

1 58. The apparatus of claim 55 further comprising means for canceling crosstalk connected
2 to the means for measuring voltage associated with each individual phase in the multi-phase
3 system, wherein the means for canceling crosstalk is connected to receive a voltage
4 measurement input for each individual phase associated with the multi-phase system and to
5 correct a voltage measurement to account for crosstalk between the phases.

1 59. The apparatus of claim 55 wherein the multi-phase system comprises three phases.

1 60. The apparatus of claim 55 wherein, for each capacitive voltage divider, the first
2 capacitance comprises a parasitic capacitance between the associated high voltage conductor

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